

CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-112

March 9, 1981

1. Name of fault.

Las Positas fault.

2. Location of fault.

Southern margin of the Livermore Valley, Alameda County, California (Livermore, Altamont, and La Costa Valley 7.5-minute quadrangles, see Figure 1).

3. Reason for evaluation.

Part of a 10-year program to evaluate and zone active faults (see Hart, 1980).

4. List of references.

Bonilla, M.G., J.J. Lienkamper, and J.C. Tinsley, 1980, Surface faulting near Livermore, California, associated with the January 1980 earthquakes: U.S. Geological Survey Open-File Report 80-523.

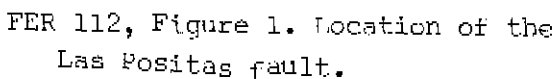
Carpenter, D.W., K.P. Puchilk, J.L. Wagoner, K.G. Knauss, and P.W. Kassameyer, 1980, Status report on the geology of the Lawrence Livermore National Laboratory site and adjacent areas (preliminary draft): Lawrence Livermore Laboratory, 2 vols.

Dibblee, T.W., Jr., 1980, Preliminary geologic map of the Livermore quadrangle, Alameda and Contra Costa Counties, California: U.S. Geological Survey Open-File Report 80-533-B.

Ellsworth, W.L., and S.M. Marks, 1980, Seismicity of the Livermore Valley, California, region, 1969-1979: U.S. Geological Survey Open-File Report 80-515.

Ford, R.S., et al., 1970, Livermore and Sunol Valleys, evaluation of ground water resources through 1968: California Department of Water Resources, Memorandum Report (modified by Ford, 1973, personal communication).

Hart, E.W., 1980, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42.



Herd, D.G., 1975, The Las Positas fault--an active, northeast-trending left-lateral fault in eastern Alameda County, California: Geological Society of America Abstracts with Programs, V. 7, p. 1110-1111.

_____, 1977, Geologic map of the Las Positas, Greenville, and Verona faults, eastern Alameda County, California: U.S. Geological Survey Open-File Report ~~70-1670~~ 77-689.

Holden, K.D., 1976, Complete Bouguer anomaly map of the Livermore Valley area California: U.S. Geological Survey Open-File Map 76-761.

Huey, A.S., 1948, ¹⁰Geology of the Tesla quadrangle, California: California Division of Mines Bulletin 140.

Merrill and Seeley, Inc., 1980, Evaluation of surface faulting hazards, Livermore general planning area, California: Unpublished consulting report for the City of Livermore. (C # 389).

Smith, D.P., 1981, Evaluation of the Verona fault and portions of the Williams Las Positas, and Pleasanton faults: California Division of Mines and Geology Fault Evaluation Report Fer-104 (unpublished report in Alquist-Priolo Project files).

URS/John A. Blume & Associates, 1978, Seismic and geologic investigations of the Sandia Livermore Laboratory site: Unpublished consulting report ^{for} Sandia Laboratories (C # 368).

5. Aerial photographs used:

U.S. Air Force, 1968, Black and white aerial photographs, Flight 059V, # 67 to 68, scale approx. 1:90,000.

U.S. Department of Agriculture, 1940, Black and white aerial photographs, BUT series, Flight 340, #53 to 60, 88 to 93, and Flight 341, #44 to 46, and 49 to 51, approximate scale 1:24,000.

U.S. Department of Agriculture, 1950, Black and white aerial photographs, BUT series, Flight 3G, #77 to 80 and 109 to 113, scale 1:24,000.

U.S. Geological Survey, 1973 Color, Low-sun aerial photographs, Frames 5-5 to 5-7, scale approximately 1:24,000.

6. Summary of available information:

The Las Positas fault, originally mapped and named by Herd (1975; 1977), is a zone of left-lateral strike-slip faults. Herd depicted the fault as a 15-km long zone, truncated at its northeastern end by the Greenville fault, and concealed by landslide deposits and Pleistocene alluvium at its southwestern end (see Figures 2A, 2B, and 2C).

Herd's depiction of a northeast-southwest trending left-lateral slip fault was a radical departure from earlier workers. For example, Huey (1948) and Ford (1970) both postulated that a series of northwest trending faults were present and cut Plio-Pleistocene gravels present in the Livermore Valley. Their postulated faults included the Tesla, Corral Hollow, Carnegie, Greenville, Mocho, Livermore, and other faults. In contrast, Herd found no evidence to support the existence of any of these faults beneath the valley, except for the Greenville and Carnegie fault^S. He depicts the Tesla fault as being truncated at its western end by the Greenville fault, well south of the Livermore Valley.

Recency of faulting.

Herd (1977, p. 7-8) indicated that his third youngest alluvial unit, older alluvial unit 2 (late Pleistocene), is clearly cut by the fault. He infers, based on a ground water barrier, that his second youngest alluvial unit, older alluvial unit 1 (late Pleistocene) is also faulted. However, since no scarp was visible in alluvial unit 1, he believes that the latest fault movement occurred prior to the deposition of the last of alluvial unit 1. He also cites the existence of left-laterally deflected drainages, fault scarps, and other geomorphic features indicative of recent movement along the Las Positas. Along the west bank of Arroyo Seco, Herd and Brabb (1979) concluded that the base of the "A" soil horizon had been displaced by fault movement along the Las Positas.

Perhaps the hardest age data was developed by Carpenter, et al (1980). In their trench E-3, they were able to obtain a C^{14} date of $17,400 \pm 250$ years, and observed a faulted alluvial sequence which included some beds younger than the dated bed. They state (p. 79) that this wood fragment was obtained from Herd's older alluvial unit 2.

Bonilla, et al (1980), reported that right-stepping en echelon fractures of probable tectonic origin were observed in two locations along the Las Positas fault after the January, 1980, earthquake (see Figure⁵ 2A and 2B). They also reported 6 mm of left-lateral post-earthquake displacement at their location 35 (an alignment array on Las Positas Avenue, see Figure 2A). The main rupture associated with this earthquake occurred along the Greenville fault. They also identified additional fractures along the Las Positas fault which they felt may not have been tectonically formed. Although Carpenter, et al. (1980, p. 48-53) indicate there is some doubt as to the cause of these fractures, they conclude that the most plausible theory explaining their existence is that fault movement occurred along the Las Positas fault.

The Existence and Definition of the Las Positas Fault

Herd (1977) depicts the Las Positas fault as a narrow zone of mostly buried faults southwest of Arroyo Mocho. ^{ASTER} Northeast of Arroyo Mocho, he shows a wider, more complex zone of faults (see Figure 2A, 2B & 2C). D. Smith (1980) suggested that the Las Positas fault may consist of two sub-parallel faults in the Livermore quadrangle. He cites the existence of left-laterally deflected drainages, scarps, and similar features along these postulated faults eastern half of the quadrangle. However, he also indicates that an 8-meter high terrace appears to not be offset in the vicinity of Arroyo Road.

URS/Blume and Associates (1978), in an investigation of the Sandia Laboratory, discounted their own air photo and trench observations, and instead relied on geophysical data. They concluded that the Las Positas fault probably does not exist. However, they found "suggestive but inconclusive evidence" of the Las Positas fault in three trenches. This suggestive evidence included the abrupt termination of strata, the existence of thin, nearly vertical clay lenses, ^{and} zones of vertically oriented gravel clasts (most others were horizontally

oriented), as well as other features. They note that Holden (1976) shows a gradual gravity gradient roughly along the trend of the Las Positas but discount the possibility that this gradient is fault related.

In contrast to the URS/Blume and Associates (1978) report, Carpenter, et al (1980), and Herd and Brabb (1979) have observed fault features in trenches and other excavations. The latter two reports both indicate that recent faults were found along geomorphic features (hill fronts and breaks in slope), and that slickensides observed indicated oblique, but predominantly left-lateral, slip.

D. Smith (1980), URS/Blume and Associates (1978), and, Carpenter, et al. (1980) all reported that they detected fairly well-defined lineaments along the Las Positas fault approximately as mapped by Herd (1977). Merrill and Seeley (1980) believed Herd's data warranted the City of Livermore's establishing an interim ^{Special} Studies Zone along the Las Positas pending the State Geologist's evaluation.

Other Faults

As noted earlier, several other, northwest-trending, faults have been postulated by Huey (1948) and Ford (1970). URS/Blume and Associates (1978) concluded that, based on geophysical data the Tesla fault probably exists. However, they note that no such fault is reflected in Holden's (1976) gravity map, and that they did not detect any evidence of faulting in a trench which they excavated across their postulated Tesla zone. Similarly, Carpenter, et al (1980), did not detect any evidence of the Tesla fault in trench E-6.

Indeed, it appears that even Huey (1948) and Ford (1970) lack any direct evidence for the existence of the Tesla, Corral Hollow, or Livermore faults at the surface in the Livermore Valley. Ford deals wholly with subsurface data, and Huey indicates he could not follow these faults through and north-

ward of the Livermore Gravels. All other investigators (except Herd) have found only "faint linears" on photographs, or inferred the faults existed based on linear hillfronts or other limited data. Herd (1977) clearly states that no northwest-trending faults exist in the Livermore Valley between the Calaveras and Greenville fault zone.

7. Field investigations; air photo interpretation.

The results of my air photo interpretation are ^e depicted on Figures 3A, 3B, and 3C. In general, I agree with Herd (1977) as to the location of the fault traces northeast of Arroyo Mocho. However, the location of the fault to the southwest is less clear. I do not agree with Herd's location of the fault in the La Costa Valley quadrangle, but instead suggest that D. Smith's (1981) version is more likely. However, evidence for the postulated northern branch of the Las Positas shown by Smith is not as continuous as he indicates. Although Smith reports an 8-meter high terrace is not offset, the fault possibly could exist along Dry Creek, and not pass beneath the terrace as Smith implies. I note Herd shows this terrace to be underlain by his older alluvial unit 1. A well-defined scarp is present just to the southwest, in Herd's older alluvium 3. With the exception of the scarp just noted, the fault features southwest of the alluviated Livermore Valley are less continuous and less well defined. These features tend to be "softer" data, consisting of tonals, benches, linear drainages, and one possible deflected drainage, all of which could conceivably be of non-tectonic origin and, except perhaps for the latter features, do not indicate the relative age of the postulated fault.

In the Altamont quadrangle, the Las Positas consists of a much wider zone of features. In general, all the features noted were sub-parallel, with greater divergence as one approaches the Greenville fault. The Greenville, itself, although the site of recent fault rupture, appears to consist of a zone, as much

as 4000 to 5000 meters wide, near its junction with the Las Positas. However, to the south, in the Cedar Mountain quadrangle, the Greenville is characteristically a very narrow zone. When one compares the location and trend of the Greenville north and south of the Altamont quadrangle, it appears the zone is broadly "offset" by about 5 thousand meters in a ^{right} ~~left~~-lateral sense, the opposite of the postulated sense of displacement along the Las Positas. Theoretically, therefore, extension should be occurring along the Greenville fault near its junction with the Las Positas. The absence of a well-defined, single through-going Greenville fault (instead several sub-parallel zones of faulting appear to exist based on air photo interpretation) would support this hypothesis. And, dip-slip movement (north side down) along the Las Positas would be expected as well.

I attempted to observe the fractures reported by Bonilla, et al. (1980). The hardest evidence they described for historic displacement was a broad zone of right-stepping fractures along Tesla Road east of Mines Road (see Figure 4A). However, this section of road has been repaved since the earthquake. The fractures they observed at other locations along the Las Positas lacked any evidence of a right-stepping pattern, and, in the case of the Mines Road fractures (see Figure 4B), would actually be left-stepping if one were to relate them to the trend of the Las Positas.

8. Seismicity.

Ellsworth and Marks (1980) analyzed the seismicity of the Livermore Valley area. They noted a "markedly lower level of seismicity" along the Calaveras fault and within the Livermore Valley during the 11 year-period studied. However, most of the focal plane solutions are consistent with left-lateral strike-slip movement along the Las Positas and right-lateral strike-slip movement on the Greenville and Calaveras faults. Some thrust solutions

are also reported in the area of the Verona fault. Ellsworth and Marks conclude that, although the Las Positas is "probably seismically active", but the data are insufficient to "unambiguously demonstrate seismic activity" (see Figures 5 and 6).

9. Conclusions.

Carpenter, et al, (1980) have demonstrated that the Las Positas fault has probably had movement along it during the last 17,400 \pm 250 years, and conclude the latest fault movement is probably Holocene in age. Herd (1977). D. Smith, and T. Smith (this report) generally agree on the locations of the principal strands of the Las Positas, (in the Livermore and Altamont quadrangles) and suggest that ^{parts of} the fault may have been active during the Holocene. Site specific investigations by Carpenter, et al., and Herd and Brabb (1979) have demonstrated the recently active fault can be found with existing technology. URS/Blume and Associates (1978) trench and air photo data also support the existence of faults (in deposits of an age similar to that ^{dated at} ~~of~~ the Carpenter, et al, site) in the Las Positas zone, although they conclude (wrongly, I believe), based solely on selected geophysical data, that the fault does not exist.

The historic left-lateral movement along the Las Positas postulated by Bonilla, et al (1980) may have occurred. However, the evidence for historic fault slip is equivocal. The measured post-earthquake slip of 6 mm did not occur immediately adjacent to any zone of right-stepping fractures; and, where such fractures were observed, the zone was quite unlike those found along other creeping faults or the nearby Greenville fault. And, there is a possibility that the measured offset may be due to other than faulting since the nails are near the edge of a highly crowned roadway. Bonilla et al, do not precisely indicate where the offset was measured within the array.

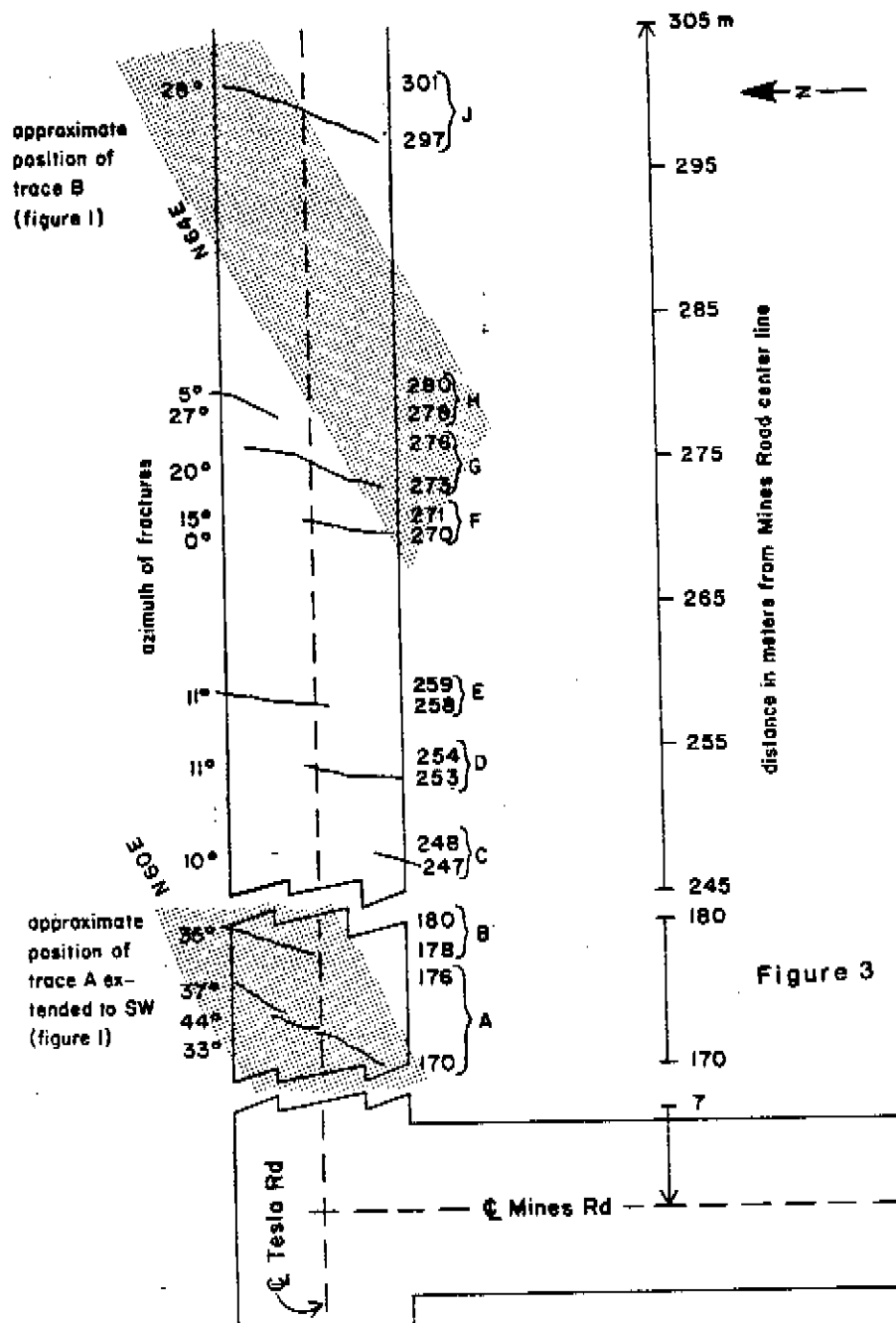


Figure 4A. Sketch map showing fractures in the pavement of Tesla Road in relation to the centerline of Mines Road and the approximate positions of traces of the Las Positas fault zone. Reprinted from Bonilla, et al (1980, Figure 3).

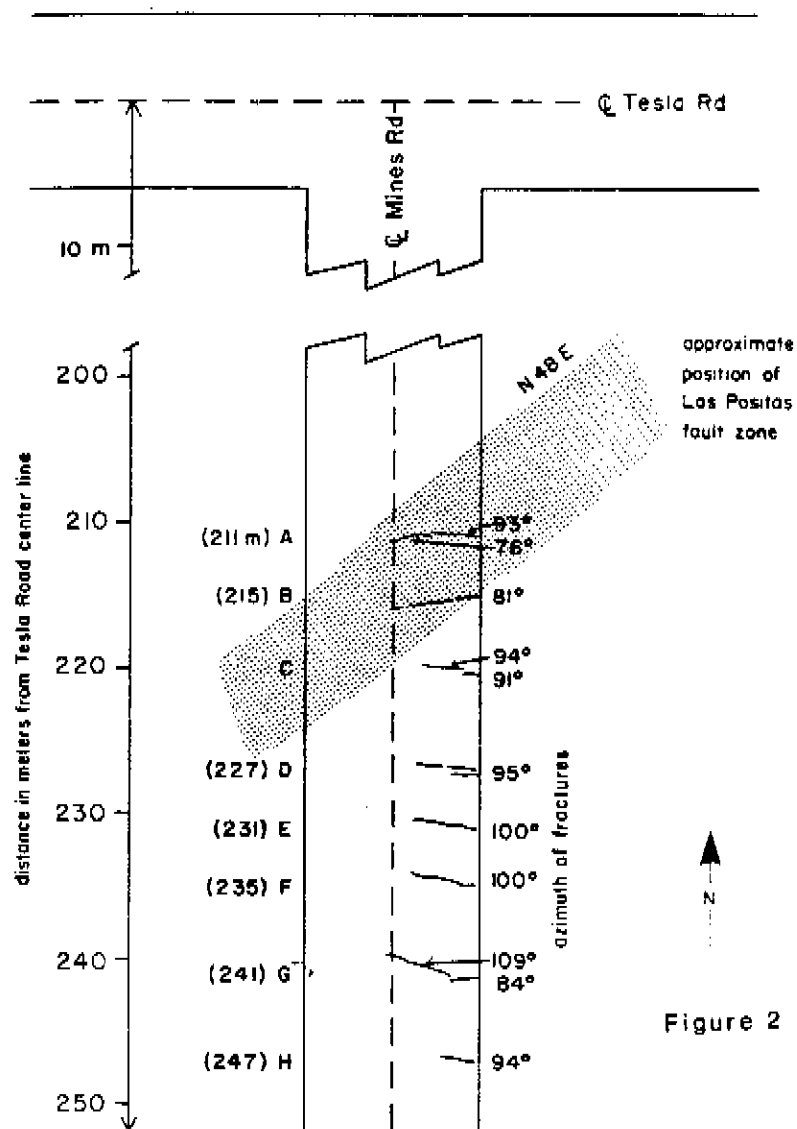


Figure 4B. Sketch map showing fractures in the pavement of Mines Road in relation to the centerline of Tesla Road and the approximate position of the Las Positas fault zone. Reprinted from Bonilla, et al (1980, Figure 2).

Figure 5. Epicenters in the Livermore region, 1969 to 1979 (from Ellsworth and Marks, 1980, Figure 3).

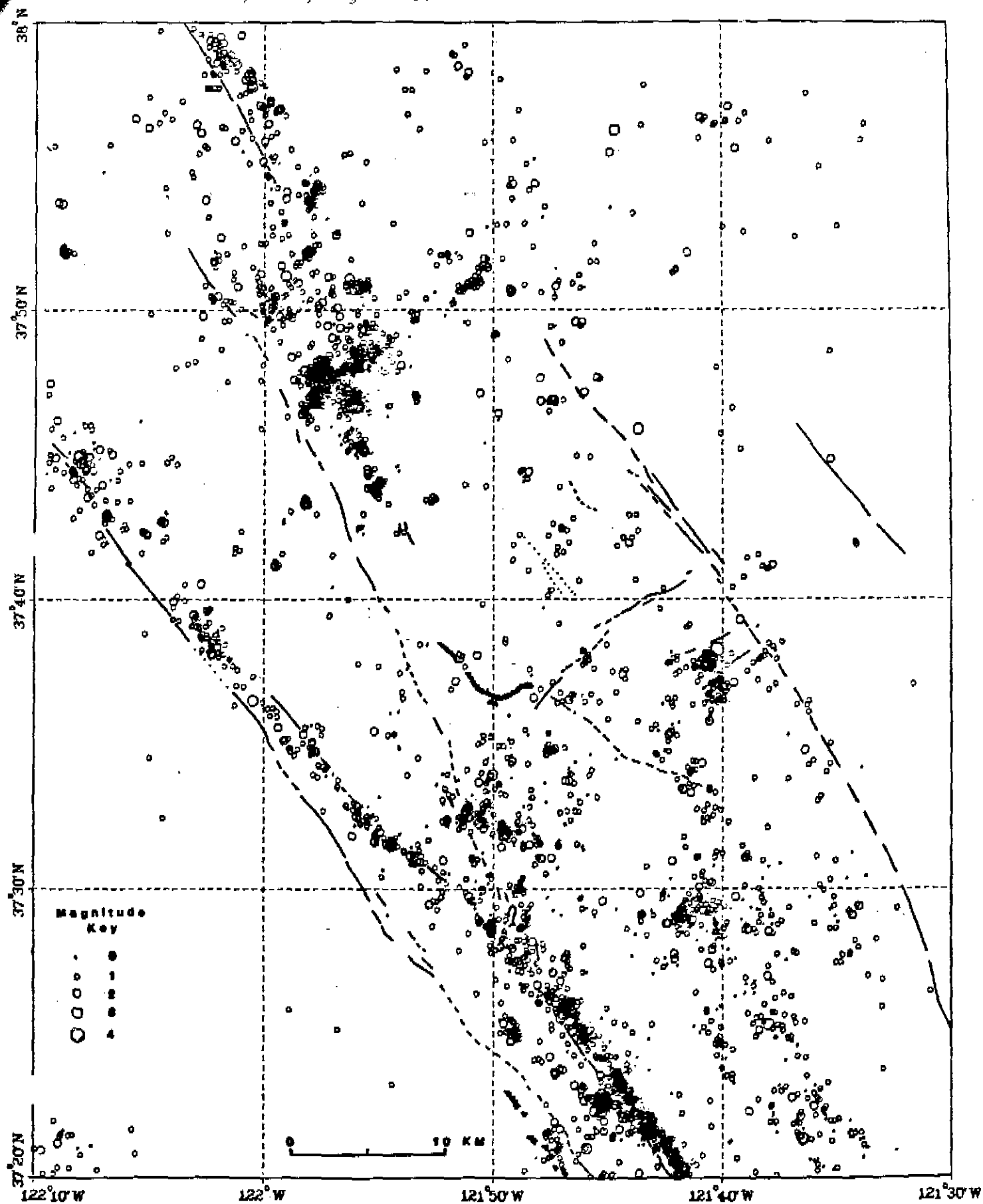
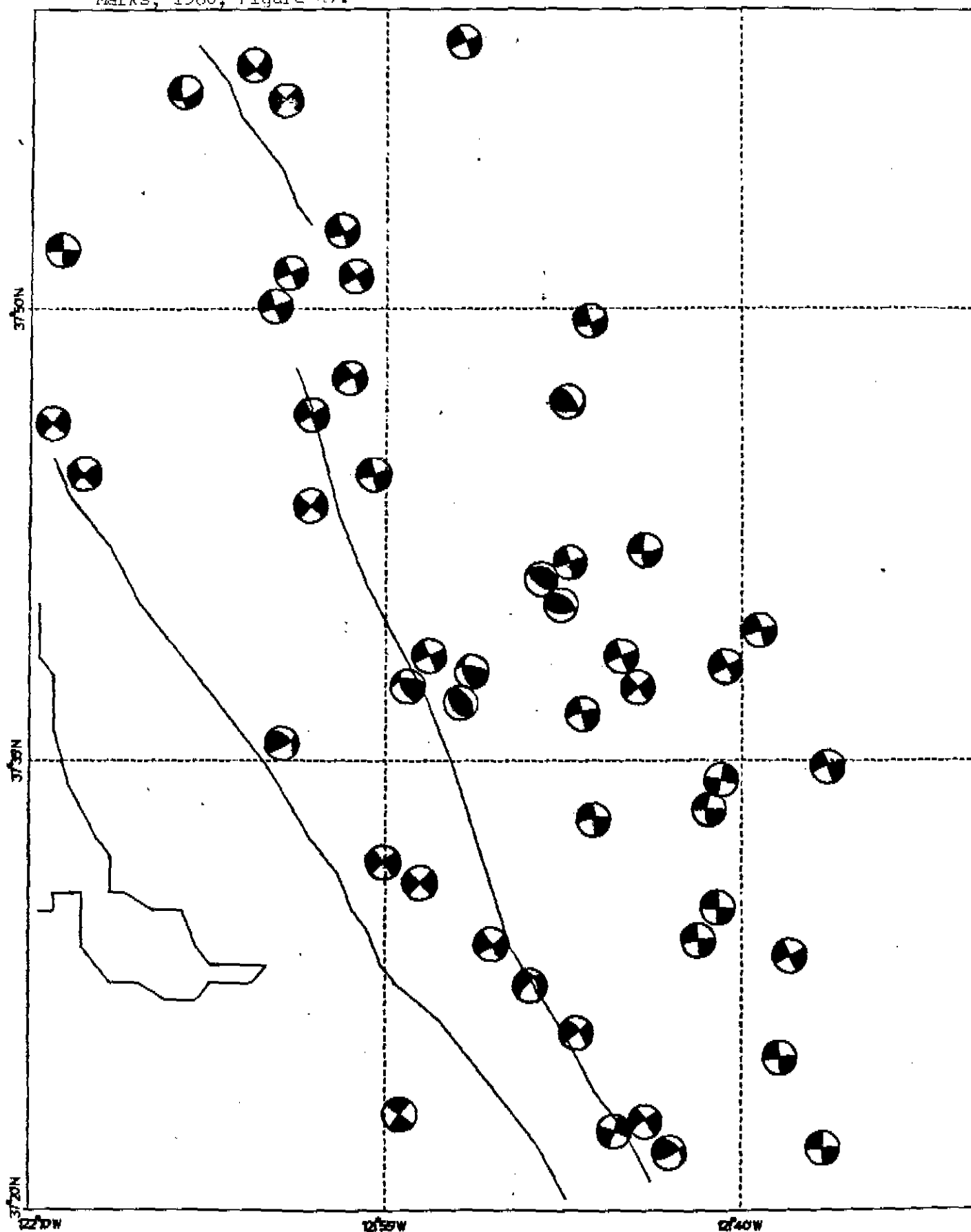


Figure 6. Selected focal plane solution, Livermore region (from Ellsworth and Marks, 1980, Figure 4).



Although the evidence is still lacking to conclusively demonstrate that surface fault rupture occurred during Holocene time, the likelihood that such occurred is great enough to warrant zoning. Individual fault strands are very well defined in the area northeast of Arroyo Mocho, where the fault appears to consist of more than one strand. ~~ff~~ Between Arroyo Mocho, and the area just west to Arroyo del Valle, the fault is much less well defined, but features suggestive of faulting can still be detected in places. Herd shows the fault as concealed by older alluvial unit 4 (late Pleistocene) indicating the fault is pre-Holocene. ^{in this latter area} Therefore, ^{this segment of} the fault does not meet the criteria of sufficiently active in this area.

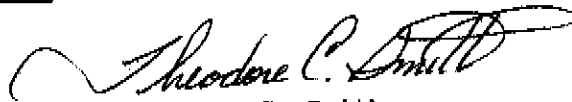
Southwest of the alluviated valley, (mostly in the La Costa Valley quadrangles), the Las Positas is poorly defined. The Livermore Gravels (Plio-Pleistocene in age) are old enough that numerous, pre-Holocene, faults may be found in the unit. The dating of the recency of such faults would likely be inconsistent, given the present state-of-the-art as practiced by most consultants. Given the absence of evidence of Holocene movement, this fault segment is not sufficiently active to warrant zoning. ~~ff~~ The existence of the southern strands of the Las Positas zone mapped by Herd ^{ve} has not yet been verified by site-specific investigations. The possibility exists that the south-facing scarp may not be fault produced, but instead may be entirely the result of erosion by the waters of Arroyo Seco. I did verify the existence of a general escarpment along this trend, and it is conceivable, though not probable, that a fault (late Pleistocene) exists along this trend. Since Herd's older alluvial unit 2 is not cut by the fault (see Figure 2A), and since Carpenter, et al (1980), dated a similar unit nearby as 17,400 \pm years old, the fault does not appear to be sufficiently active to warrant zoning.

The northeast-trending fault located east of Lawrence Livermore is shown only as cutting Livermore Gravels (Plio-Pleistocene) and buried under older alluvial unit 3 (late Pleistocene). Therefore, this strand does not appear to be sufficiently active to warrant zoning.

10. Recommendations.

The sufficiently-active and well-defined segments of the Las Positas fault, as described above, should be zoned, based on work of Herd (1977) in the Altamont quadrangle. The remaining segments (the fault east of Lawrence Livermore and the southern strands in the Altamont quadrangle, and all fault segments southwest of Arroyo Mocho) should not be zoned. The faults and Special Studies Zones should be depicted approximately as shown on Figures 7.

11. Investigating Geologist Date.


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March 9, 1981

TCS/map

*I agree with
the recommendations.
EdH
3/30/81*